Interview: Michael B. Duke

Lunar ice will enhance development of the Moon

Dr. Michael Duke has been a leading advocate for human space activities on the Moon for more than 15 years. A geochemist, Duke began his professional career at the U.S. Geological Survey during 1963-70. He then became the curator of the lunar samples brought back by the Apollo astronauts, working at NASA's Johnson Space Center (JSC). From 1977 to 1990, Duke led the Solar System Exploration Division at JSC. In March 1983, less than two years after the first flight of the Space Shuttle, Duke organized sessions at the 14th Lunar and Planetary Science Conference in Houston to discuss options for returning people to the Moon. Under his guidance and initiative, NASA and the National Academy of Sciences followed up this initial meeting, with a major conference in Washington, D.C., titled "Lunar Bases and Space Development in the 21st Century," in October 1984. Space visionary Krafft A. Ehricke keynoted that conference. From 1990 to 1996, Duke was the assistant director for the Space Science, Space and Life Sciences Directorate at JSC, and for the past few months, he has been Senior Project Coordinator at the Lunar and Planetary Institute in Houston.

Dr. Duke was interviewed by Marsha Freeman on Jan. 16.

EIR: Recently there has been an exciting discovery announced by scientists looking at data from the Clementine mission, that there are strong indications there is ice at the south pole of the Moon. Isn't it the case that such a discovery had been expected by scientists, as early as 1961?

Duke: People understood theoretically that if there were water molecules released by any sort of process on the surface of the Moon, they would tend to migrate to the dark cold places at the poles, and that really is a property of the Moon that exists because of the peculiarities of the lunar orbit. That is, the Moon rotates perpendicular to the Sun—I think the angle is about 1.5 degrees—so that any depression near the pole has an opportunity to be permanently shadowed, and, therefore, always cold. Temperatures are low enough that water molecules would migrate to them.

That was proposed, in 1961, by Ken Watson and Bruce Murray. Murray was just a young scientist at the time, working with Harrison Brown at Cal Tech, who wrote a paper on that subject. The possibility has been known for a long time. The Clementine data are the best experimental evidence, I guess, that exists right now.

EIR: In the 1961 paper, where they did they think the water had come from?

Duke: That was at a time before we'd gone to the Moon, so there was still speculation that the Moon had a lot more water than we subsequently found. I believe that they thought that most of the water would have come from volcanic emanations into the lunar atmosphere.

EIR: Is it the view of the people who are looking at the Clementine data, that the water molecules that have accumulated have come from cometary impacts?

Duke: There was a later model, and paper, written by Jim Arnold, at the University of California, San Diego, in 1979, in which he re-examines the question of ice at the lunar poles, and on the basis of things that we had learned in the lunar program, we learned that there wasn't any significant amount of internal water that could have come to the surface and collected at the poles. But he pointed out that there was good evidence that the steady rain of micrometeoroids on the lunar surface could bring some water. We know that in some meteorites there are hydrated minerals—that is, minerals that actually contain water in their crystal structure—and these are represented in cosmic dust, and surely are raining down on the Moon, so that is something of a source of water.

We also know that in the lunar samples, there is evidence of the reduction of iron oxides and the production of water. The reduction of iron oxide occurs because hydrogen coming out of the Sun, in the solar wind, is implanted into the surface of grains in the soil. When they are subsequently hit by meteorites or micrometeorites and melted, there is a reduction. The hydrogen reacts with the iron oxide, and metallic iron is produced in the samples; this is a quite well-documented feature in the impact glasses [created when the Moon's surface is hit by a meteorite] that exist on the surface of the Moon. And if the iron is there, the other product of that reaction must have been water. Some of the water would have escaped, and some of it could be trapped at the poles of the Moon. So, those are two sources of water.

It is now thought that probably the largest source is from comets that impact the Moon. Arnold's model tried to quantify the magnitudes of what those sources would be. Arnold was actually interested in trying to understand how much water there might be, not just what the sources were. He tried to quantify how much water there could be.

EIR: The discovery has been made on the basis of indirect evidence, using radar and the reflection of the surface. One would like to get more data, either confirmation or refutation of this idea. The Lunar Prospector will leave for the Moon next September. What will that spacecraft add to our knowledge of ice on the Moon?
Duke: It will have another experiment on it that is capable of, again, an indirect experiment. It will look at the way neutrons are emitted from the surface of the Moon. Neutrons are produced when cosmic rays hitting the surface of the Moon react with the surface materials, and a certain amount of these neutrons are scattered back into space. Hydrogen molecules are very strong absorbers of these neutrons, so, if there is water present at the poles, you should see a difference between the neutron spectrum as the spacecraft passes over the poles, from what you see at other places on the Moon. It's like a remote-sensing experiment.

The problem with the neutron experiment is that its resolution is not very good. I don't know how many data points it could get, going over the south pole of the Moon, but its spatial resolution on the surface of the Moon is typically about the same as the altitude of the spacecraft. So, if the altitude of the spacecraft is 100 kilometers [km], then it can't resolve things on the surface that are closer together than about 100 km, so it may get only a few points, even if there is ice there, and won't help locate or determine exactly where the ice is. It can only really tell you that ice is present or water is present.

So, it will remain for some other experiment, in particular, we think surface experiments, to go looking for the ice, to actually characterize where it is, how much it is, how thick it is, and so forth.

EIR: So, you would want to land a spacecraft at the pole?
Duke: We have in mind a small rover, which would be landed in areas where there is light, near the south pole, and be able to charge its batteries while it's daytime, and then go into these cold, dark spots for relatively short periods of time, a few hours, maybe as much as 20 hours. It would be able to look around. It would have an illumination source so it could take pictures of the surface. It would have a drill that allowed you to probe maybe as much as a meter below the surface; take samples; analyze the samples to see if there were volatile materials; determine what kinds of volatile materials, and how much was there, and hopefully, what

As can be seen in this composite photo of the south pole of the Moon, taken by the Clementine spacecraft in 1994, the Aitkin basin covering the pole, at the center, is in permanent shadow. These dark regions form cold traps that allow water molecules to accumulate, and form ice.

sort of variation there would be with depth. One of the really exciting scientific things, is that if there is water there, and it is preserved, then there should be layers that are associated with individual comets which have hit the Moon. If you could, in fact, read a record on the Moon of the history of comet impacts, maybe you could start telling something about the difference between comets, and how many comets have hit the Moon over different periods of time.

EIR: Is there a reason that you would expect to find water ice at the south pole, and not at the north pole of the Moon?
Duke: The data from Clementine suggest that there is more permanently shadowed territory at the south pole than the north pole, and that is the case because, apparently, in the period 4 billion years ago, or even earlier than that, there was a major impact located in the vicinity of where the south pole now is, and there is a depression called the south pole Aitken basin, which has lowered the surface level of the Moon around the south pole as much as 20 km. So there is essentially a dimple in the Moon, in the vicinity of the south pole, and some of the landscape is just below the mean level of the surface and, therefore, more likely to be shadowed than at the north pole.

EIR: So it is a question of the ice remaining there because it is colder at the south pole, but at the north pole it would evaporate in the sunlight?
Duke: Any place where the Sun is able to hit the surface,

either directly or even indirectly, bouncing off other features, the temperatures will be warm enough that ice cannot exist over the periods of time that we are talking about. What will happen is that when the Sun shines on a place where ice has formed, the ice will be vaporized and the volatiles will go hopping around, looking for another cold place to alight. So, over a long period of time, the water will migrate to the very coldest places. The ice, except for the case of comets, is essentially precipitated molecule by molecule, and is the result of a water molecule jumping around the surface until it finds a cold place, that is so cold that it doesn't get activated again, to jump away.

EIR: Although we do not know how much ice there may be there, mixed in with sand and other material, what are the consequences of this, in terms of the future development and use of the Moon?

Duke: If the model that was put together by Jim Arnold in 1979 is correct, there are very large amounts of water in these cold traps. If you take his estimates of how much water there might be there, and you take the Clementine estimates of how much area is in permanent darkness, you come up with a number of 1 to 2 meters of water ice over these cold trap areas, which are estimated to be about 15,000 square km [in area]. So if the model is correct, there would be 15 million cubic meters of ice. A cubic meter of ice is effectively a ton of ice, so that's 15 million tons of ice, distributed over a fairly large area.

It would be a very significant supply of ice. To characterize that: There is, to a first approximation, a one-to-one relationship between water and the propellant that you might use in a chemical rocket, let's say, to go to Mars. If you use a hydrogen-oxygen rocket, then the proportions of the hydrogen and oxygen are about the proportions in water, so if you have a kilogram of water you can turn it into a kilogram of rocket fuel. When we talk about sending human missions to Mars, we typically talk about several hundred tons of propellant, out of several million tons of water available [on the Moon]. So you can see that if going to Mars were your objective, you would have the wherewithal of sending many, many missions to Mars.

That's not the way I would use it, but that gives you an idea of how much, and how important, that ice really is.

EIR: It would seem that a nearer-term use for the ice on the Moon would be to support a human presence on the Moon, without the burden of having to bring water from the Earth.

Duke: That is true, and the biggest burden of supporting people on the Moon is the propulsion system to get them there and back. The existence of water on the Moon would have a major influence on the transportation system that you use to get people to the Moon and back. The amount of water that is needed to support humans on the Moon is quite small, compared with the amount that is effectively used to get them there or to get them back to Earth. Even if there are large amounts of water, it is essentially a nonrenewable resource, so you would want to use it in a way that is most productive.

My feeling is that it would be most useful in allowing a human outpost on the Moon to grow rapidly, and then to find other ways of either providing propulsion off the Moon that didn't use chemical propellant, or developing some other sources of water that could be used if you were going to continue to depend on chemical propellants.

What I have in mind is, for example, in early stages to use lunar water as part of your propellant supply. You would use up a certain amount of water but, at the same time, you might be developing electromagnetic propulsion, mass drives, to get back and forth to the lunar surface, and when you have electromagnetic launch capability, you won't any longer need the water for chemical propellant.

EIR: So it provides a transition.

Duke: Yes, it's a stepping stone that makes it relatively easy to get started, which is a really important feature in space development. The biggest barriers that exist to space development are the initial barriers of developing technologies and capabilities. If we had, for example, heavy-lift launch vehicles, we would be ready to do lunar missions, lunar exploration, and development. The fact that we don't have heavy-lift launch vehicles, and that they are very expensive to develop, stands in the way. The first and largest expenditure in any of the lunar exploration plans that have been put forward, is the heavy-lift launch vehicle. And we haven't been able to get over that barrier. So, anything that reduces the magnitude of the initial barrier to get things done is of considerable value.

EIR: You have participated for many years with the international lunar exploration community in taking a look at reviving manned lunar programs. Is there any ongoing work that can fold into mission planning, the possibility of using water ice on the Moon?

Duke: It's an obvious thing to do. I am not aware that anybody is doing it right now. Over the next few months to a year, you will start to see some reports coming out as to the implications of ice on the Moon for lunar exploration and development. There are a few people who have speculated in the past, but there is no body of work that is based on the assumption that water is actually there.

EIR: There has been tremendous financial pressure put on the space agency in this country, and, now, also in Europe and Russia, which unfortunately leads to a situation that limits people's thinking of what can be done in the future. I don't think the assumption should be made that the constraints on the space program now will necessarily always be there. I think one should plan for what one thinks should be done, and not simply look at what fits into present cost constraints.

Duke: You can lay all sorts of plans, but they don't amount to much if you can't implement some of it.

EIR: That is certainly true, but there were plans being made to land men on the Moon, decades before it was able to be done. They knew it was going to have to be done, at least on a certain scale. Recently, there has been planning going on inside NASA, also involving people not in the space agency, to take a look at what could be done when the international space station is operational, after the turn of the century. But the driver is the cost—not the mission, not the science—and that kind of planning can get to a level of absurdity.

Duke: The problem is that nobody has been able to figure out an evolutionary way to do it. That's why the lunar ice may be important, because it allows you some additional degrees of freedom in an evolutionary approach, which allows you to bootstrap your way up the curve. The folks at JSC, Kent Joosten and his colleagues, looked at a scenario for the Moon which was somewhat more evolutionary and had a smaller scale than the previous typical lunar exploration programs. They were able to demonstrate that you didn't need a Saturn V-class launch vehicle if you had access to propellants on the Moon, because the size of the launch vehicle was essentially dominated by the mass of the spacecraft that you would use, to come from the Moon back to the Earth. If you had to land it with its propellant, it has a mass about twice that of a spacecraft that could land if it doesn't have to carry its propellant. So, the availability of propellant on the Moon would reduce the scale of the mission by about a factor of two, and thus reduce the cost and size of the heavy-lift launch vehicle.

EIR: But, that is making the assumption that you are doing this the way Apollo did it. That is, starting from the surface of the Earth, and landing on the surface of the Moon. But, in the meantime, you've built the Space Shuttle system, and you will have a space station, so it would seem that it is not necessary to do it directly.

Duke: Nothing really has changed. It's a matter of where you stage the system, where you make the breaks between launch of various space systems. But the physics still require that you launch something from the surface of the Earth with a chemical launch system, and we don't have anything but chemical rocket systems for the utilization of space. Until we have something like nuclear propulsion systems, or solar thermal propulsion systems, or mass drivers, we'll basically still be on the same paradigm of masses and payload fraction that are dictated by chemical propulsion.

EIR: I wanted to raise this question of development of propulsion technology. One idea that has been put forward, called Mars Direct, would start from the surface of the Earth and end up on the surface of Mars, and not make any use of the infrastructure that you have, and not make any use of the Moon as an intermediate stage. This is based on the idea of doing the mission within 10 years, and is, therefore, dependent upon using chemical propulsion technology. This is a three-year mission, submitting the crew to a lack of gravity and interplanetary radiation.

As an intermediate step, using the Moon—both because there are reasons to develop the Moon regardless of going further, and because it can be a way-station to Mars—it seems would give you the time to develop the nuclear and other propulsion technologies that would give the manned mission a comparable level of risk to that of the Apollo program.

Duke: I agree with that completely, and I think that within NASA there is a belief that that is true. I know that it's shared by [JSC Director] George Abbey and Mike Mott [NASA deputy associate administrator], and other people, particularly those who were associated with the Synthesis Group in 1990, who looked at the Space Exploration Initiative. They concluded that the leap between sending people to the Moon for three days at a time, and sending people to Mars for months to years, is so great, that we need an intermediate step of activity on the Moon.

But, I have to say that there are strong forces at work, at least in the popular space science community, and to some extent, the scientific community, that are very focussed on Mars. Even back in 1984, I was surprised when we had that first symposium in Washington on lunar bases, that there was a strong community of people that said, "Why are you doing the Moon? You should be going to Mars." It is just popular, and it is the focus of scientific programs, whereas the Moon has basically dropped out of any real focus in the science program. So there is a lot of interest, and a lot of people, who believe that we should drop everything and focus on Mars missions.

I am actually more interested, personally, in developing the concepts of how the Moon can be useful, economically and scientifically, than I am in using it as a way point to Mars; but I think that it is a reasonable step in a program that gets you to Mars, for a lot of reasons. They are essentially the ones that you stated: experience of technology needs to be developed before we can be comfortable sending people to Mars.

EIR: At the meeting of the American Astronautical Society in Houston in December, you made the statement that the problem in finding a useful synergy between the lunar and Mars missions has been that the recent lunar mission planning activity did not include the development of new technologies.

Duke: Right. There's been, for some reason, a focus on doing lunar missions quickly, and that generally means without developing any new technology. The Dan Goldin focus has been figuring out how to do it more cheaply. My interpretation of Goldin's objectives in "faster, cheaper, better," was that he thought that if the engineers were challenged by having to focus on ways of doing things more cheaply, they would respond by becoming cleverer, in figuring out new ways, new technologies, and clever ways of reducing the cost.

Most of the studies of lunar missions have not looked at clever ways of doing it, they just looked at the way in which the requirements could be reduced, to the point where the costs were lowered; how can you just do a lunar mission with the very least amount of mass launched from the Earth. So, people have looked at spacecraft that essentially have no substance. There may be a little bit of technology in there, but mostly it's, how do you reduce the requirements to the point where it can be accommodated in the budget you have?

EIR: In that kind of situation, you would not have any synergy with Mars exploration.

Duke: The only things that I think have shown signs of really being synergistic in that regard, are those strategies that attempt to utilize planetary resources, as part of the exploration strategy. There are some for the Moon, and there are things like Zubrin's [Mars Direct] idea. It is only partially dominated by his objectives of doing it soon. The basic thing that differs about Zubrin's architecture from architectures that were looked at in the past, is the utilization of resources on Mars, which works in the way I was describing before. If you provide the propellant on Mars to get people back to Earth, you reduce, by a very large amount, the mass that you have to launch from low-Earth orbit. That's the real thing that his architecture is focussed on.

EIR: He is certainly not the first person to think of that. Space visionary Krafft Ehricke did his most extensive work on lunar industrialization, but he did quite a bit on Mars, as well. There were numbers of people who knew you wanted to use *in situ* resources.

Duke: It's obvious, and people should have recognized it. People are starting to feel more comfortable with the idea now, and it's almost mainstream in Mars exploration circles.

EIR: It is also true, however, that if you developed more advanced propulsion technologies, you would not have to worry about carrying this large mass of fuel to and from Mars. Local resources will be important on the Moon, regardless of whether or not they are used for propulsion systems.

Duke: The reason I have been interested in the propulsion aspect is because if you look at the motivation to develop the technology, it is very difficult to get people to invest in technology that will help you in a broad range of things in 20 or 25 years. There's nobody who is interested in doing that, except the government, and people look for a nearer-term application. So, the development of *in situ* propellant for lunar or Mars missions is something that, if you develop the technology, you may be able to sell it to the government to use it on a near-term exploration mission, even though you realize that downstream the market for your product may be very different, and used for a wide variety of purposes. The initial impetus to develop it can be provided by the need for propellant.

EIR: I think it is going to be only governments which will see the need, and come up with the resources, for any kind of long-range program for space exploration—and this is true internationally. You are very involved in lunar planning missions, which it seems to me are very important to continue. Even if these plans are not implemented now, small-scale technology development can proceed until larger steps can be taken.

Duke: I think you're right. I'm hoping—in particular, for the Moon—that this discovery, and, later, the verification, that there is water ice at the poles, will provide some additional stimulation for that.

EIR: There are indications that the agenda for the White House space summit in February will be very practical, with the goal of stabilizing the funding for NASA for the next few years, but not with any long-term goal.

Duke: It will have accomplished something if just the baseline budget gets maintained, rather than facing that 20% or 25% cut that it looked like it was facing last year. And that doesn't really allow any new programs until the space station is much further along.

EIR: It seems to me, people are looking toward the time when spending on the space station is going down, and you can begin to fold in spending on a new program, as long as the budget is not declining.

Duke: I think that it is really important to have identified those next programs and start having advocacy and constituencies for them. Because, otherwise, NASA would naturally fall into this situation where they would continue the operational programs—Space Shuttle or space station, built and running, which you just continue to operate—and they would use up all the money in the budget, and never go forward anywhere, just because it's the thing that we know how to do, and we feel comfortable doing it, and it gets a certain amount of attention.

But the real question is, once we have developed the space station, is there a wedge of resources that is available for doing other things, or does it get eaten up by the current programs, or taken away by the Congress? The question is whether there will be resources available when the space station spending starts to decline.

I think it is really important not just to study things, but to actually do things, and I hope that some of the recent discoveries will motivate us to invest in the technology development so that we have at least prototypes that can be demonstrated, that people can get interested in and excited about, and actually getting us doing things, rather than just writing articles and papers about them.